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Introduction

The Materials and Research Department has conducted a study of materials and specifications for reflective sheeting highway signs. The study was made in response to a request from Mr. G.G. McGinness, Acting Engineer, Service and Supply, to Mr. F.N. Hveem on February 24, 1954. Mr. McGinness asked that all known data relative to materials now marketed be assembled and analyzed and that specification limits be set for the following properties of reflective sheeting:

A. Reflectance Values
B. Surface Texture
C. Color Retention
D. Adhesives and methods of applying reflective sheeting to base material

Interim specifications and items of general information regarding reflective sheeting qualities have been supplied to interested Division of Highways personnel as the information became available throughout the study.

This report is submitted to summarize information previously supplied, disclose further information available at the conclusion of the tests, and describe the methods used in making the study.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A REPORT ON

FIELD EXPOSURE TESTS OF FIVE TYPES OF REFLECTIVE SHEETING MATERIAL

February 28, 1958

State of California
Department of Public Works
Division of Highways
Materials and Research Department

Lab. Proj. Auth. 85-R-6016

Mr. G. G. McGinness, Acting Engineer
Service and Supply Department
Public Works Building
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT ON

FIELD EXPOSURE TESTS OF FIVE TYPES OF

REFLECTIVE SHEETING MATERIAL

Study made by . . . . . Structural Materials Section
Under general direction of . . . . . J. L. Beaton
Supervised by . . . . . H. A. Peterson
Report prepared by . . . . . R. N. Field and C. N. Miller

Very truly yours,

F. N. Hveem
Materials and Research Engineer

RNF/CNM:mw
cc: J. W. Trask
R. R. Norton
Department Heads
District Engineers

58-25

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INTRODUCTION

The Materials and Research Department has conducted a study of materials and specifications for reflective sheeting highway signs. The study was made in response to a request from Mr. G.G. McGinness, Acting Engineer, Service and Supply, to Mr. F. N.Hveem on February 24, 1954. Mr. McGinness asked that all known data relative to materials now marketed be assembled and analyzed and that specification limits be set for the following properties of reflective sheeting:

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CONCLUSIONS

A. Reflectance Values

The Traffic Department of the State of California, Division of Highways, has expressed the desire for a reflective sheeting with high reflectance values at a wide angle of light return. Of the five materials tested, Scotchlite wide angle flat top was the only reflective sheeting that complied with this requirement.

Reflectance measurements are shown in Figures 13, 14, and 15. Specifications used for comparison purposes are those published by the Service and Supply Department dated December 1955 and revised May 1957.

B. Surface Texture

The surface of reflective sheeting must be of such a texture that oil and road smears are readily removed by maintenance crews. Scotchlite wide angle, Grote, and Reflexite reflective sheeting met this requirement.

Scotchlite exposed bead and Fre-lite reflective sheeting were difficult to clean. Oil, mud, and road smears adhered to the surface and left permanent stains.

C. Color Retention

When the reflective sheeting test plates were subjected to prolonged field exposure (two years) the following color changes occurred:

Scotchlite wide angle and Reflexite reflective sheeting did not fade appreciably.

Scotchlite exposed bead silver panels were subject to slight bleaching, and the red and yellow panels were subject to slight fading.

Grote red and yellow panels faded slightly. The silver panels changed from silver to a dull white.

Fre-lite reflective sheeting panels faded objectionably.

D. Adhesives and Methods of Applying Reflective Sheeting to Base Materials

Two types of separation of materials may occur in reflective sheeting during field exposure.

1. Separation of the reflective media from the aluminum foil backing. This type of peeling is accompanied by oxidation of the aluminum foil, and occurs most extensively in the Coastal area. All reflective sheeting included in this study, with the exception of Reflexite, peeled in this manner when the edges were not protectively sealed.

2. Separation of the reflective sheeting from the aluminum base plate. Fre-lite reflective sheeting peeled in this manner. All other reflective sheeting materials adhered satisfactorily to the aluminum base metal.

E. Durability

Scotchlite wide angle and Scotchlite exposed bead reflective sheeting resisted weathering satisfactorily. The materials remained flexible and did not crack, peel, or blister.

Reflexite reflective sheeting was too brittle to provide satisfactory field service.

Fre-lite reflective sheeting panels did not weather satisfactorily.

Tests of Grote reflective sheeting were discontinued after 16 months exposure because of complete failure of panels installed in the Coastal area.

F. Aluminum Alloy Base Metal

Aluminum alloy 6061 T6 served as a satisfactory plate metal for reflective sheeting signs in all locations except those in the Coastal area. All panels in the Coastal area indicated that oxidation or corrosion detrimentally affects the adherence of the reflective sheeting material (see Figure 12). If aluminum is to be used for signing along coastal highways, it should be edge-sealed and protectively covered. When this is done, the reflective sheeting panels withstand the salt air exposure satisfactorily and are thus a satisfactory medium of signing as long as the protective coating is properly maintained.

G. Specifications

In December 1955, as a result of initial reflectance readings of the five types of reflective sheeting tested, new specifications were written for reflective sheeting for use until final results were available from field exposure tests. At the termination of field tests, all initial and final reflectance data were analyzed and new specifications were written. These specifications, dated May 1957, supersede the 1955 specifications and are currently in use by the Service and Supply Department of the Division of Highways.

RECOMMENDATIONS

Subsequent to the fabrication of the reflective sheeting panels used in this test in 1955, some manufacturers have improved the reflectance characteristics of their reflective sheeting products. It is therefore planned to continue this program on a permanent basis. Reports will be issued from time to time as new developments seem to warrant such reporting.

We plan to use the following locations as permanent test sites:

Eureka Maintenance Yard, District I

Sacramento Laboratory Roof, District III

Truckee Maintenance Yard, District III

Cambria Maintenance Yard, District V

Lemoore Maintenance Yard, District VI

Palm Springs Maintenance Yard, District VIII

SELECTION OF MATERIALS FOR TESTING

A survey was made of many manufacturers of reflective sheeting and analysis made of their products in order to select the most promising types of sheeting to subject to field tests. The following five types of sheeting were selected for testing:

1. Type SF - Scotchlite, wide angle flat top; silver, yellow, and red
2. Type SS - Scotchlite exposed bead; Signal Silver, Sunset Yellow, and Flame Red
3. Type R -- Reflexite; silver, yellow, and red
4. Type F -- Fre-lite; silver, yellow, and red
5. Type G -- Grotelite; silver, yellow, and red (no longer commercially supplied)

The reflective sheeting will be referred to by the letter code representing each type throughout this report.

PREPARATION FOR FIELD EXPOSURE TESTS

A. Manufacture of Panels

All reflective sheeting used in the test was mounted on 8" x 24" aluminum alloy plate. Reflexite sheeting was mounted on an aluminum plate of unknown alloy. All other types of sheeting were mounted on aluminum alloy 6061 T6 plates. Mounting holes were provided in the plates so that the panels could be attached to existing guide posts. Thus, it was possible to mount the reflective sheeting panels along the roadway for cleansing, impact, and durability tests. Each type of reflective sheeting was applied to the aluminum base plates by the respective manufacturer. In this way the proper method of application and curing was assured. The completed panels were not edge-sealed or protectively coated in any manner.

B. Location of Test Areas and Installation of Panels

The three test areas selected are representative of the varying climatic conditions existing throughout the state. Five silver panels of each type were installed at each roadway site. Six panels of each type (2 red, 2 yellow, 2 silver) were installed at each maintenance yard test site. The panels were mounted in a vertical position on the test racks, one plate of each type and color facing north and one of each type and color facing south.

1. The Valley Test Area

The roadway site is located in District VI, on VI-Kin-125-C, near the junction with section D, 4.7 miles south of the town of Stratford on State Route 41.

The guide posts are spaced 225 feet apart on both sides of the two-lane highway which runs southwest to northeast. A total of five silver panels of each type was installed on the guide posts, two of each type facing north and three of each type facing south. The complete installation extends for approximately one-half mile along the roadway.

The maintenance yard test site is located in the southern corner of the Lemoore Maintenance Yard in the town of Lemoore, 34 miles south of Fresno on State Sign Route 41. The test rack faces north and south. This installation (see Figure 1) was completed on June 13, 1955.

2. The Desert Test Area

The roadway test sites are located in District VIII. One roadway site is near Palm Springs on VIII-Riv-26-D, and the other is three miles north of Palm Springs on VIII-Riv-187-D. All guide post panels at the test site located on Riv-26-D were mounted in the median strip near an opening on a four-lane divided highway. The plates were mounted two feet from the pavement, with the top of the plates three feet above the ground (standard guide post installation). A total of five silver panels of each type was installed on the guide posts, two of each type facing north and three of each type facing south. This roadway installation runs southwest to northeast.

At the site located on Riv-187-D (a four-lane divided highway) four plates of each type were installed facing south, and one plate of each type facing north.

All south exposed plates installed on VIII-Riv-26-D are subject to severe sand erosion.

The maintenance yard test site is located in the northeast corner of the Palm Springs Maintenance Yard, five miles north of the city of Palm Springs on State Sign Route 111 (see Figure 2). The exposure rack, which faces north and south, was installed on June 16, 1955.

3. The Coastal Test Area

Existing wood guide posts in this area were not readily adaptable for reflective sheeting tests. Therefore, no roadway coastal tests were conducted.

The maintenance yard test site is situated in District V in the Cambria Maintenance Yard, one mile north of the city of Cambria on State Sign Route 1. The exposure rack (see Figure 3), 100 feet east of the highway and 300 feet from the ocean edge, was installed on June 21, 1955.

INSPECTION DURING FIELD EXPOSURE TESTS

Reflective sheeting panels remained in the field installations for a period of twenty-four months. The roadway panels were inspected annually and notations were made of their condition. At the end of nine months and twenty-four months the maintenance yard panels were removed from the exposure racks and returned to the laboratory, where they were tested for reflectivity and inspected for surface texture, peeling, cracking, and fading.

RESULTS OF FIELD EXPOSURE TESTS

Results of field exposure tests are divided into two general classifications. The first, comprising the environmental effects in a given test area on all types of reflective sheeting, is discussed in item A below. The other, comprising durability characteristics of each specific type of reflective sheeting, is discussed in item B.

A. Environmental Effects on All Reflective Sheeting

The average reflectance values as reported in Figure 13 indicate that the southern exposure is more severe than the northern exposure on the red and yellow panels of all types. Figure 13 also indicates that sun exposure of panels causes more reflectance loss in the desert area than in the other areas.

1. The Valley Test Area

The panels in the valley test area were in good condition after nine months' exposure. No evidence of peeling or base metal corrosion was present. The panels in this area resisted weathering throughout the twenty-seven month exposure period.

2. The Desert Test Area

Panels located in the desert area maintenance yard had after nine months' exposure faded more than the panels in any other test area. They had been exposed to more sunlight than had the other panels. No evidence of corrosion or oxidation was present on the aluminum base plates in the desert area. This condition prevailed throughout the twenty-four months of exposure. No peeling was evident. The only indication of impending failure was the fading of colors on the south exposed panels.

Severe sandblasting of the south exposed panels at the desert roadway test site resulted in low reflectance. It was noted that south exposed reflector buttons in this area were similarly affected by sandblasting. The reflectance of the north exposed panels was good. Similarly,

the north exposed reflector buttons were in good condition. This comparison, observed after nine months of field exposure, is made to indicate that the effects of sand erosion are the same for reflective sheeting as for reflector buttons.

After sixteen months' exposure, the sand erosion on the roadway panels had caused further deterioration. None of the types of reflective sheeting panels satisfactorily withstood the sandblasting that occurs in this area.

3. The Coastal Test Area

After nine months' exposure, the panels in the coastal maintenance yard had started peeling. Figure 12 indicates edge peeling which occurs on reflective sheeting in this area. Light corrosion was evident on the aluminum base plate. Panels had peeled and blistered more in the coastal area than in the other areas. The cause was primarily oxidation of the aluminum base plate under the sheeting rather than a deficiency in the reflective sheeting.

After sixteen months' exposure the aluminum base plates had oxidized extensively. If aluminum base plates are installed in coastal areas, some sealing or protection to deter this oxidation will be necessary.

B. Durability of Specific Types of Reflective Sheeting

A record was maintained of the durability exhibited by each specific type of reflective sheeting after nine, sixteen, and twenty-four months of field exposure.

1. Type SF Panels

After nine months the south exposed panels at the desert test area were peeling along the edge (see Figure 9). The exterior layer of beading was peeling off the aluminum foil backing of the reflective sheeting. Panels in the coastal and valley test areas had weathered satisfactorily.

After sixteen months, the panels at the valley test area had resisted weather satisfactorily. The red and yellow panels at the

coastal test area had blistered and darkened due to oxidation of the aluminum base plate under the adhesive. No oxidation was present on the silver panels.

After twenty-four months, Type SF panels had withstood exposure with fewer failures than any of the other types of panels tested. Two Type SF panels peeled slightly from natural weather conditions. The color retention was good, and loss of reflectance for the silver white panels was low.

At the termination of the field exposure period, the panels were compared by eye with unexposed control panels, and the following color changes were noted:

Silver: The panels had bleached from a silver cream color to a silver white. The bleaching was uniform for panels in all test areas and both exposure directions.

Red: The panels had dulled slightly, but the change was constant in all panels, regardless of location and exposure direction.

Yellow: All panels had faded slightly.

2. Type SS Panels

Inspection after nine months revealed that the panels at the valley roadway test site had been carved upon by vandals (see Figure 6); however, no peeling or further damage had resulted from this carving. The panels in the desert test site located on Palm Springs Highway 187-D were in good condition. They had not been subjected to the severe sandblasting prevalent in other desert areas. Signal Silver and red panels in the Coastal area had faded slightly.

Although the silver and yellow panels in the valley area were still weathering satisfactorily after sixteen months, the red panels had faded slightly. The beads were more noticeable from a slight angle of observation, giving a faded appearance in the daytime. The silver panels were dirty but were otherwise satisfactory. In the coastal test area, the signal silver panels were in satisfactory condition; however, the colored panels were somewhat faded.

Final inspection revealed that the desert area panels had faded and the coastal area panels had blistered. The silver panels in all areas had withstood exposure with few failures. The red and yellow panels in all areas had darkened.

When the field exposed panels were compared by eye with standard control panels, the following color changes were determined:

Signal Silver: The panels had bleached uniformly from a cream color to a silver white.

Flame Red and Sunset Yellow: The panels had darkened slightly, but this change was uniform for all panels in all test areas.

3. Type R Panels

After nine months' exposure the panels in the coastal area had weathered satisfactorily. Loss in reflectance was very low for panels in the desert test area.

After twenty-four months the panels at the coastal test site exposure racks were in satisfactory condition. The panels in the valley area were satisfactory in daytime and nighttime for a 0° reflectance angle.

Reflexite panels in all areas were very brittle. They shattered easily when struck and were impossible to repair (See Figure 7).

At the final inspection, reflectance values for all sheets were still high at angles of 0° and 10°. Both initial and final reflectance was very low at angles of 20°.

When the field exposed panels were compared by eye with standard control panels, the following color changes were determined:

Silver: Panels from the desert area, both north and south exposures, appeared flat or dull. Panels from the other two areas showed no change in color.

Red: These panels did not change noticeably in color or general appearance.

Yellow: The south exposed panels in the desert area appeared flat or dull. Panels from the other two areas showed no change in color.

4. Type F Panels

After nine months the panels in the valley and desert test areas were gray and dirty (see Figure 8). They did not respond to cleansing efforts when subjected to severe scrubbing and brushing. The coastal area Type F panels showed definite indications of failure due to exposure. The beading had weathered off, the panels retained road dirt, and the colors had faded extensively.

After sixteen months, the north exposed silver panels in the valley and desert test areas had peeled severely, and the red and yellow panels (subject to both north and south exposures) had faded objectionably. The red and yellow panels were gray and dirty, and small areas of the base plate were exposed. The panels at the coastal test site, as in the other areas, were discolored and gray.

Final inspection revealed that Type F panels in all locations had failed excessively. In some cases the entire panel was bare of all reflective media.

When the field exposed panels were compared by eye with standard control panels, the following color changes were determined:

Silver: The panels had faded from silver to gray.

Red and Yellow: The panels had faded severely.

5. Type G Panels

After nine months this reflective sheeting gave definite indications of failure due to exposure in all three locations. The panels had cracked and peeled between the plastic reflective surface and the aluminum foil backing. The exterior coating on the valley test area panels, particularly those in north exposures, had cracked and peeled (see Figure 4). The panels in the desert area had peeled and cracked slightly around the edges and along the bottom, apparently because of moisture. The reflective sheeting in the coastal maintenance yard had peeled off the aluminum base plate (see Figure 10).

Slight corrosion of the aluminum had occurred, but had not yet become severe.

After sixteen months, Type G panels had peeled extensively in the coastal test area. The silver south exposed panels had failed completely. Oxidation of the aluminum reflective media had caused a separation of the plastic surface from the aluminum foil.

Headquarters Laboratory was informed by the Type G manufacturer's representatives that this failure had been determined by their own organization. Consequently the manufacturer changed the types of materials and is no longer manufacturing the same type of reflective sheeting that was used during the exposure tests. The laboratory therefore discontinued any further testing of the Type G panels.

REFLECTANCE MEASUREMENTS

Reflectance measurements of the panels are tabulated in Figure 13 and shown graphically in Figures 14 and 15. The reflectance readings are reported in candle power per foot candle per square foot. No correction for color change has been made.

Since Type F and Type G panels had failed physically under exposure, the reflectance values for these types of sheeting are not included in Figures 13 and 15.

Color change due to exposure has increased reflectance readings on some types of panels.

Type R panels, though showing the greatest loss of reflectance, exhibited high initial and final reflectance values at angles of 0° and 10°. Reflectance values of Type R panels at angles of 20° were extremely low, at both initial and final measurements. Newly installed Type R panels were objectionably bright when viewed from a vehicle with headlights on high beams.

Type SF panels in the red color show an increase in reflectance value, indicating that some color change had occurred due to the physical characteristic of the matrix of the sheeting which increased the reflectance values of the red panels. Type SF silver white and yellow panels show a loss in reflectance.

Type SS signal silver panels show a loss in reflectance in all locations except the valley and coastal maintenance yard test sites. The wide angle characteristics of Type SS panels are retained after prolonged exposure, as shown in Figures 13 and 15.

Reflectance values for Types F and G panels are only slightly below the values for Type SS at angles of 0° and 10° but are significantly below the values of Type SS at angles of 20°.

APPENDIX

REFLECTANCE DATA

Color	Type Material	Test Area	North Exposure 0°* Final§ Value	North Exposure 0°* %Loss(-) %Gain(+)	North Exposure 10°* Final§ Value	North Exposure 10°* %Loss(-) %Gain(+)	South Exposure 0°* Final§ Value	South Exposure 0°* %Loss(-) %Gain(+)	South Exposure 10°* Final§ Value	South Exposure 10°* %Loss(-) %Gain(+)
Silver	Scotchlite (Wide Angle	Coastal	64	-12	58	-8	50	-29	47	-23
		Desert	53	-24	49	-18	49	-31	24	-61
		Valley	62	+3	55	-4	42	-32	39	-16
		Average	60	-11	54	-10	47	-32	37	-33
	Scotchlite (Normal Angle)	Coastal	67	+10	76	-7	69	+17	78	-4
		Desert	39	-37	35	-57	29	-54	25	-70
		Valley	69	+15	84	+4	78	+32	89	+13
		Average	58	-4	65	-30	59	-1	64	-11
	Reflexite	Coastal	138	-71	37	-16	573	+6	34	-46
		Desert	278	-59	25	-60	104	-86	8	-87
		Valley	128	-83	98	+38	131	-78	50	-14
		Average	181	-71	53	-13	269	-52	31	-49
Red	Scotchlite (Wide Angle)	Coastal	15	+15	12	+20	14	+27	12	+20
		Desert	15	0	12	-9	13	-7	11.5	+10
		Valley	16	+7	13	+8	14.7	+15	14.3	+27
		Average	15	+7	12	+6	14	+12	12.6	+19
	Scotchlite (Normal Angle)	Coastal	8.9	-18	6.4	0	9	-18	4.8	-17
		Desert	10	-17	6	0	7.7	-27	5.4	0
		Valley	9.5	-17	7	+17	8	-33	6	0
		Average	9.5	-17.5	6.5	+6	8	-26	5.4	-6
	Reflexite	Coastal	122	-39	12	-60	128	-30	9	-58
		Desert	65	-54	19	-14	31	-85	4.7	-80
		Valley	137	-34	32	+78	125	-26	14	-27
		Average	108	-42	21	+1	95	-47	9.2	-55
Yellow	Scotchlite (Wide Angle)	Coastal	19	-5	17	0	10	-50	10	-41
		Desert	8.3	-53	7.7	-43	5.7	-69	5.4	-69
		Valley	13	-28	12	-20	6	-65	6	-60
		Average	13.4	-29	12.2	-21	7.2	-61	7.1	-57
	Scotchlite (Normal Angle)	Coastal	11	-8	10	-17	10	-17	10	-17
		Desert	8.9	-25	8.9	-25	5.8	-50	5.8	-50
		Valley	10	-17	10	-17	10	-17	10	-17
		Average	10	-17	9.6	-20	8.6	-28	8.6	-28
	Reflexite	Coastal	125	-78	43	-18	122	-79	77	+8
		Desert	445	-23	50	-25	98	-80	15.6	-79
		Valley	134	-79	90	+30	128	-79	14	-22
		Average	235	-60	61	-4	116	-79	35.5	-31

* Angle of Incidence
§ Final Reflectance Value (candle power per ft. candle per square foot)

Figure 13

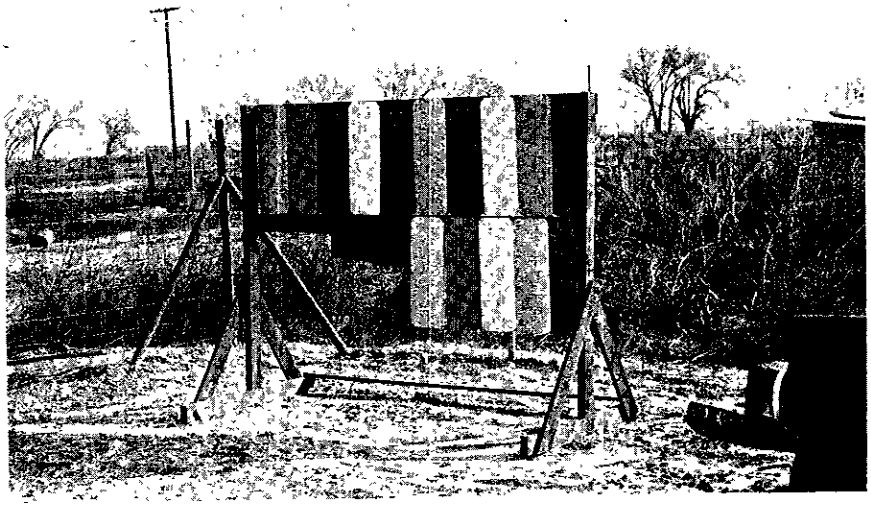


Figure 1 - Exposure Rack, District VI, Valley Area

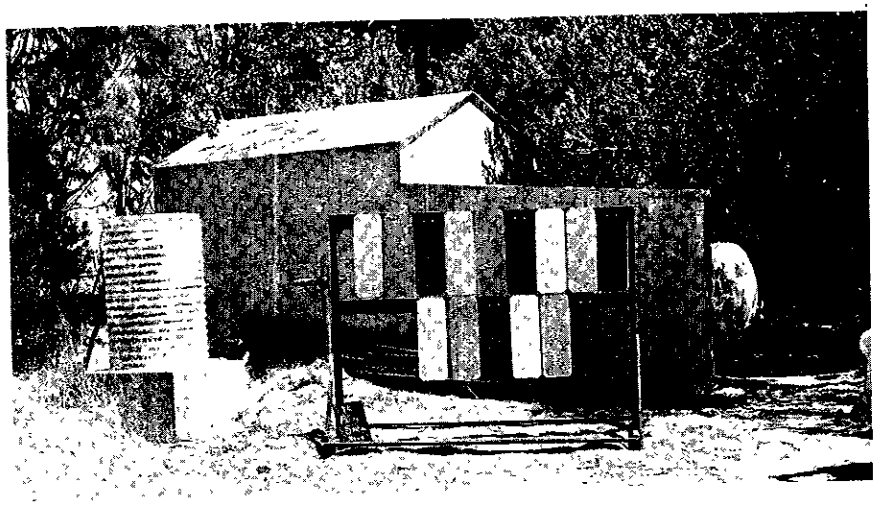


Figure 2 - Exposure Rack, District VIII, Desert Area

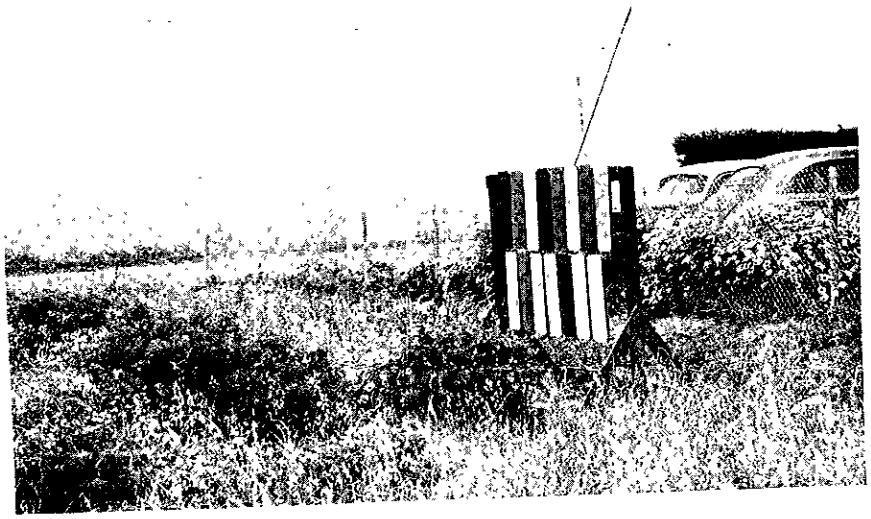


Figure 3 - Exposure Rack, District V, Coastal Area

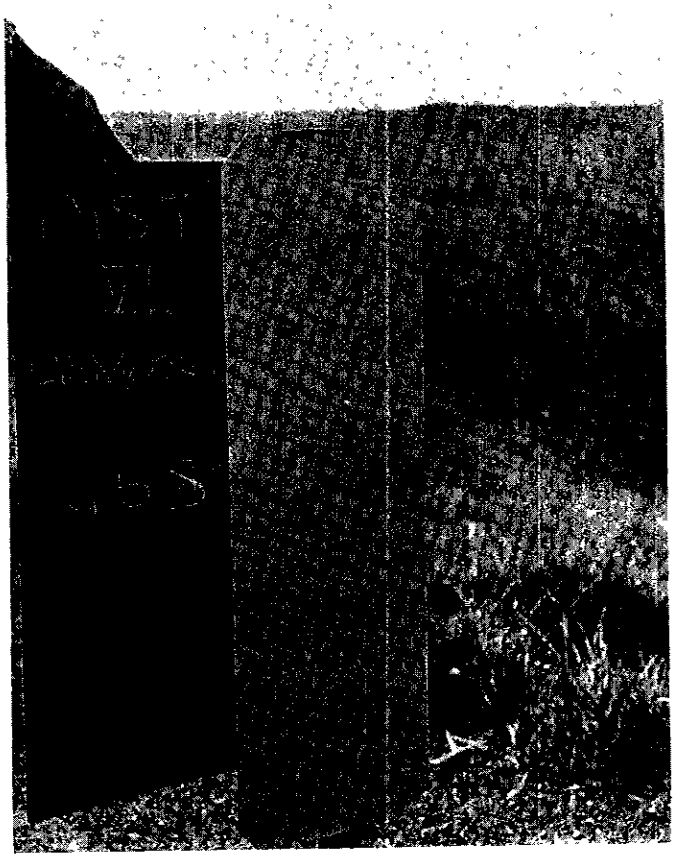


Fig. 4 Grote Silver Undamaged - Peeling on top edge after 8 months exposure.

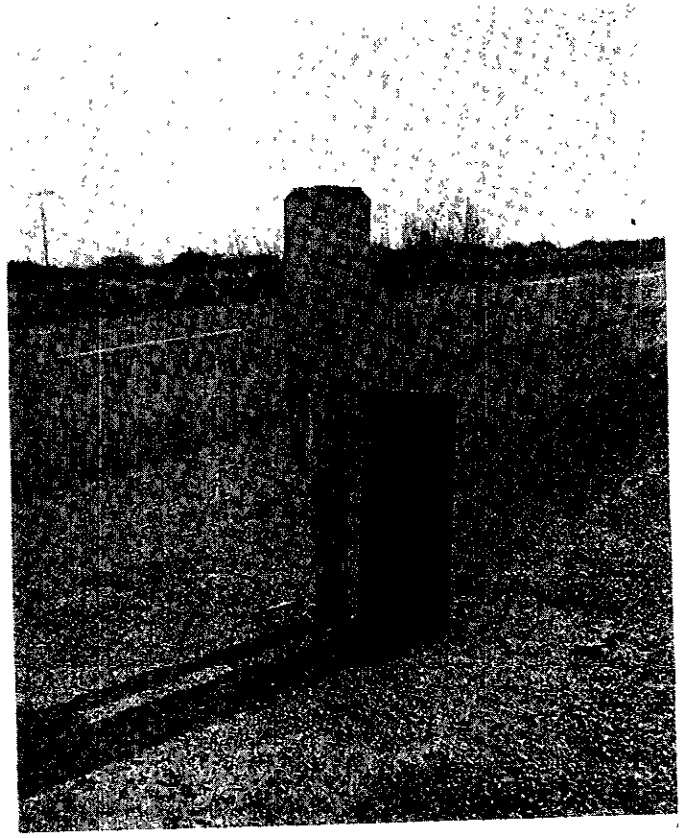


Fig. 5 Grote Silver, Damaged - Peeling on top edge after 8 months exposure.

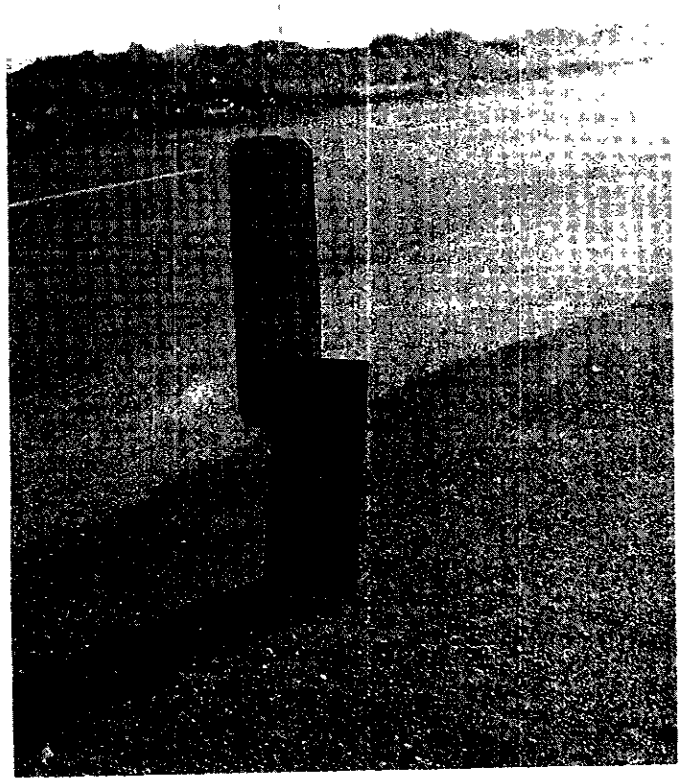


Fig. 6 Example of Vandalism.

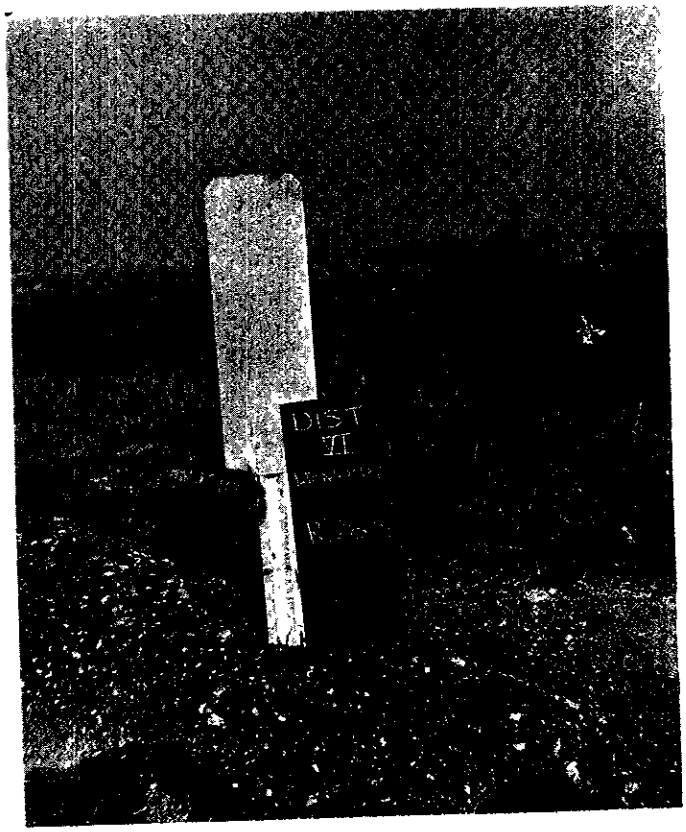


Fig. 7 Reflexite Shattered from vehicle impact.

Fig. 8 Fre-lite - Dirty and difficult to clean.

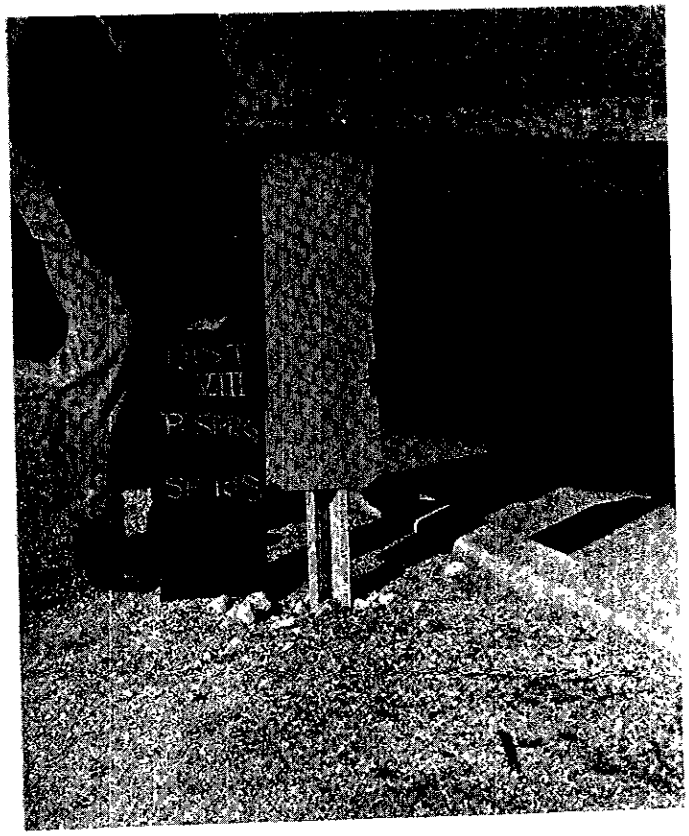


Fig. 9 Scotchlite Flat Top - Peeling along edge.

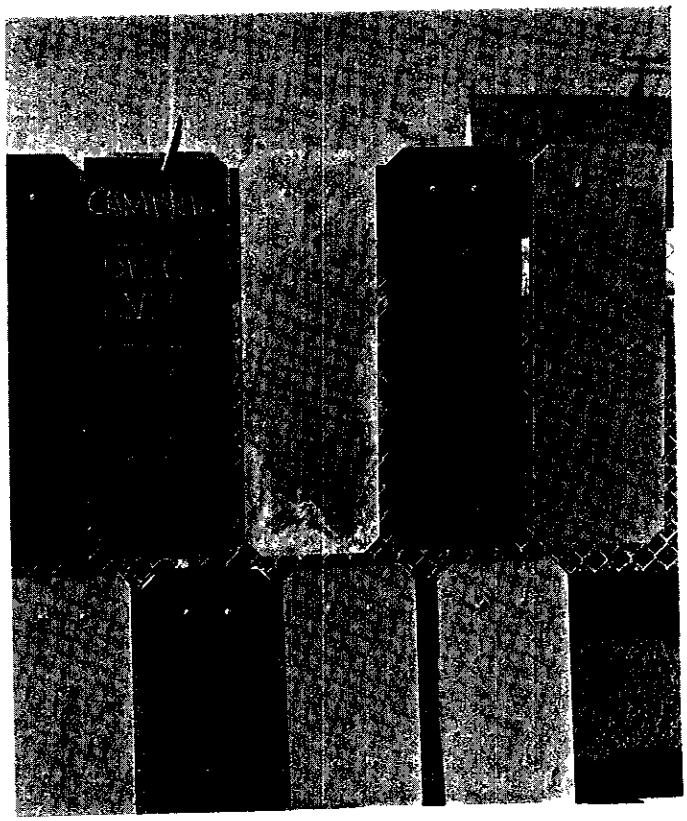


Fig. 10 Grote Silver - Peeling severely.

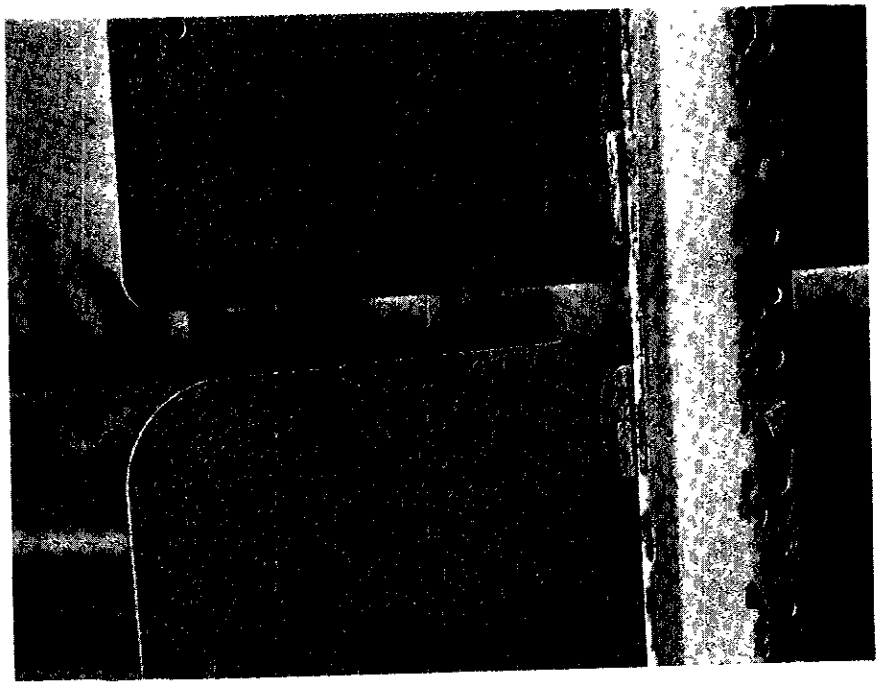


Fig. 11 Example of corrosion of aluminum backs - Huntington Beach area.

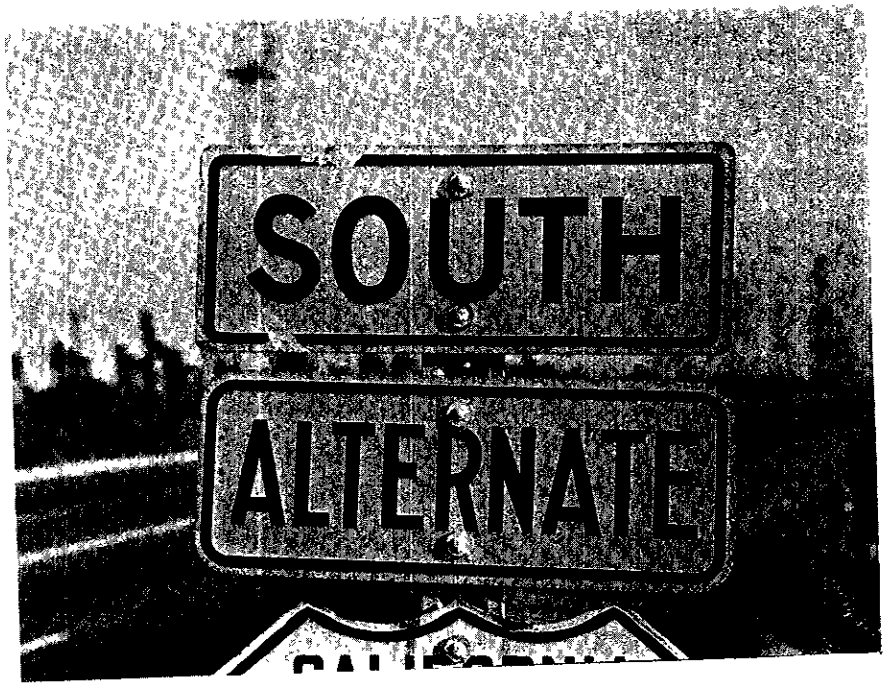
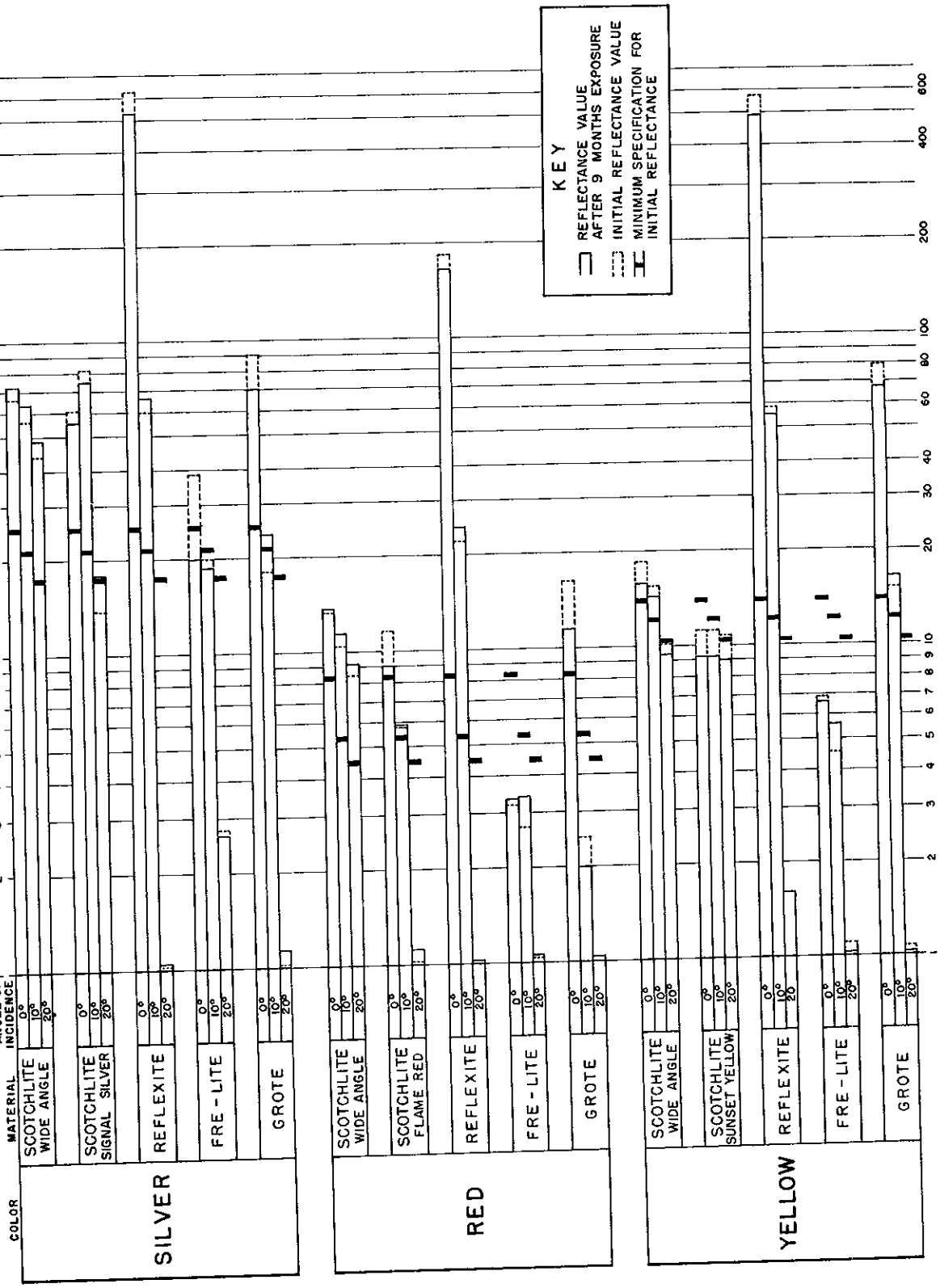


Fig. 12 Example of edge peeling of reflective sheeting.

REFLECTANCE VALUES AT 9 MONTHS
CANDLE POWER PER FOOT CANDLE PER SQUARE FOOT

AVERAGE OF VALUES, ALL TEST AREAS, BOTH EXPOSURES



REFLECTANCE VALUES AT 24 MONTHS

CANDLE POWER PER FOOT CANDLE PER SQUARE FOOT

AVERAGE OF VALUES, ALL TEST AREAS, BOTH EXPOSURES

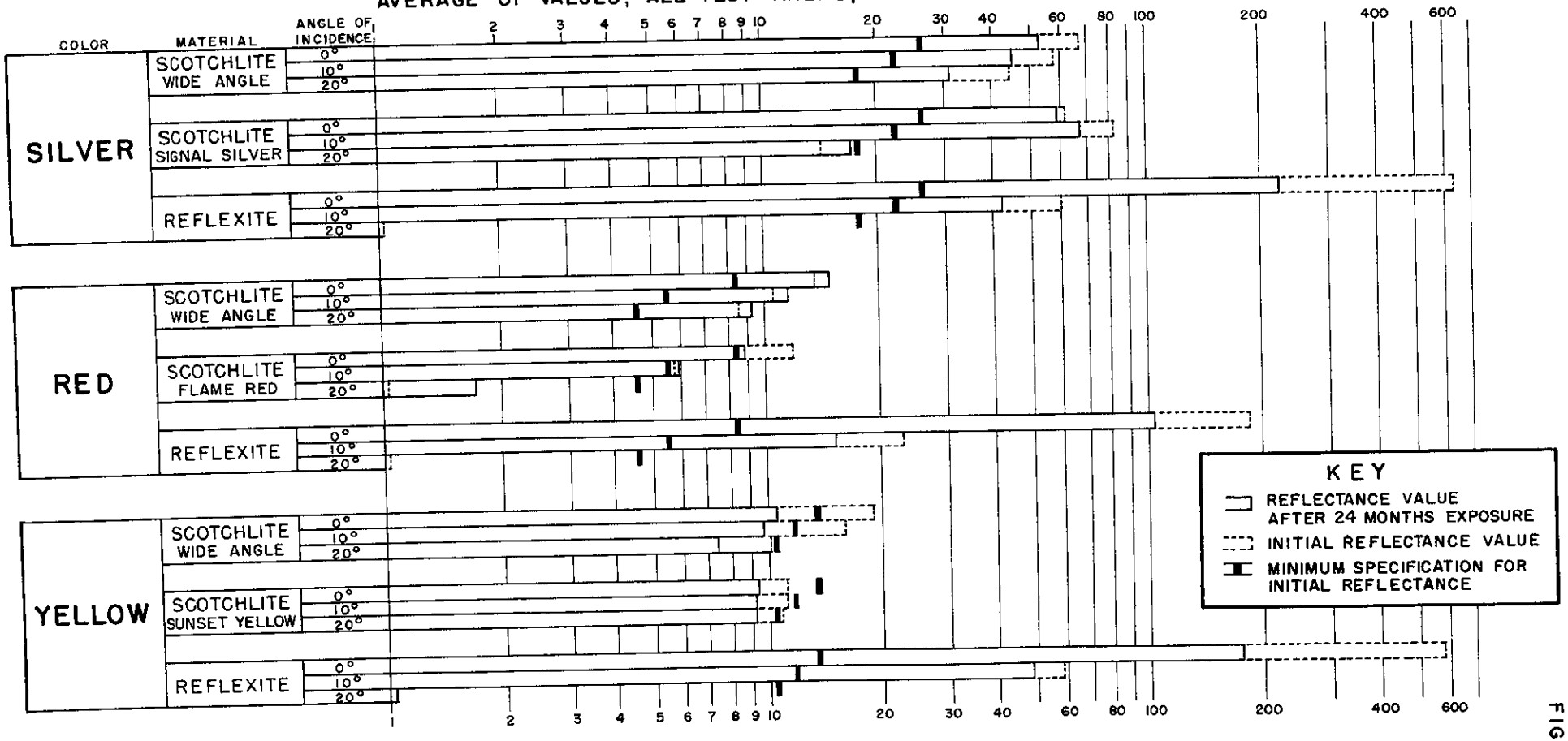


FIG. 15